Your Project Calculations

Project Name: MTSOLAR_DB6D2AH5A7DC

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=MTSOLAR_DB6D2AH5A7DC&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/8_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=oHqjrU3lq0umk7nDfIYT6qJ3JM0FdKdJNfQ6J8HSbD1Bzwyv0OejgSW1rLFfpcx1

Array Specification

Product:	Beam
Unique ID:	4P-19.75-6TOP-XD-12-L-4Hx11W-CG94
Duty Classification:	XD
Module Width:	41.10 in
Module Length:	74.00in
Number of Rows:	4
Number of Columns:	11
Total Number of Modules:	44
Desired Tilt Angle:	27
Front Edge Clearance:	3
Total Array Height at Tilt:	9.26 ft
Total Frame Length:	68.75 ft
Frame Weight:	3206 lbs
Array Dimensions N/S:	13.87 ft
Array Dimensions E/W:	68.75 ft
Rail Length:	166.40 in
Rail Spacing:	3.08 ft
Rail Check:	Not Checked

Support Specifications

Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	6.15 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 7.50 ft Pile 2: 8.00 ft Pile 3: 8.00 ft Pile 4: 7.50 ft
Foundation Volume:	8.116 y^3
Foundation Result:	PASSED
Mount Twist:	0.794493 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	93 Arnold Rd, Pelham, MA 01002, USA
Wind Speed:	105 mph
Snow Load:	40 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.018914 ksf

Design Disclaimer

This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

AutoDesigner Input


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{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"MTSOLAR_DB6D2AH5A7DC","site_address":"93 Arnold Rd, Pelham, MA 01002, USA","module_width":41.1,"module_length":74,"number_rows":"4","number_columns":11,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":27,"ground_clearance":3,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"36_Round","foundation_type":"Round","foundation_size":36,"check_rails":false}
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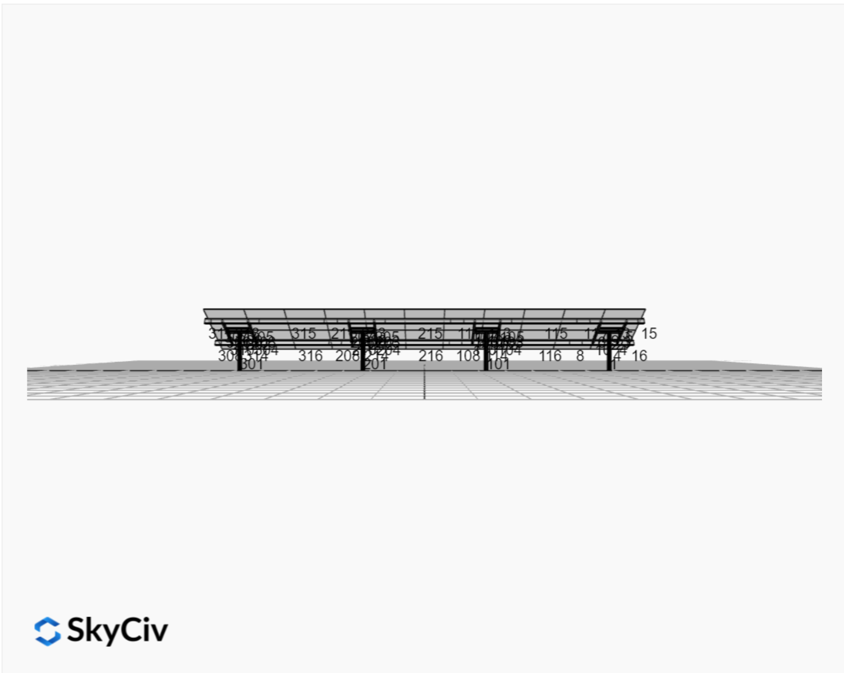
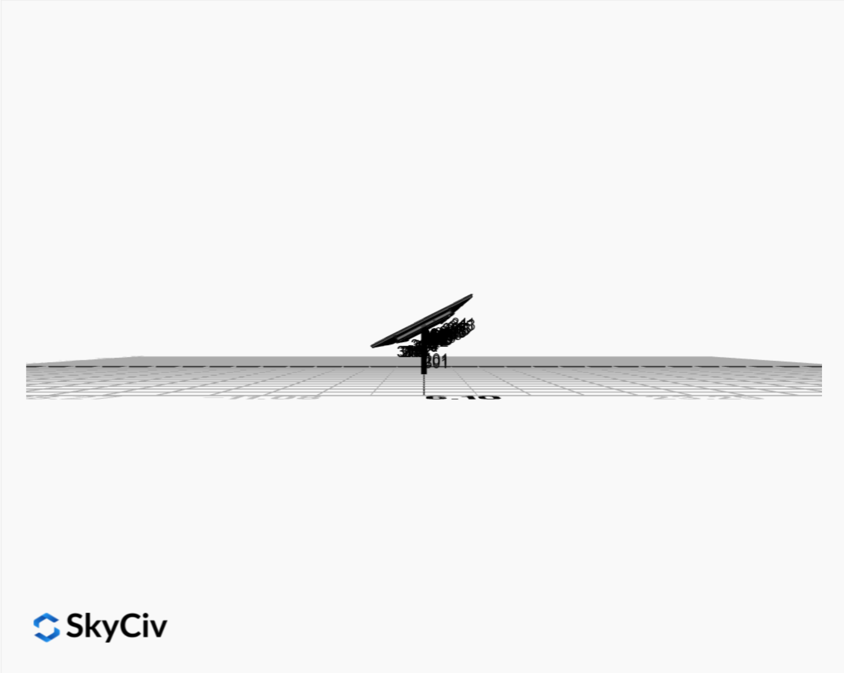
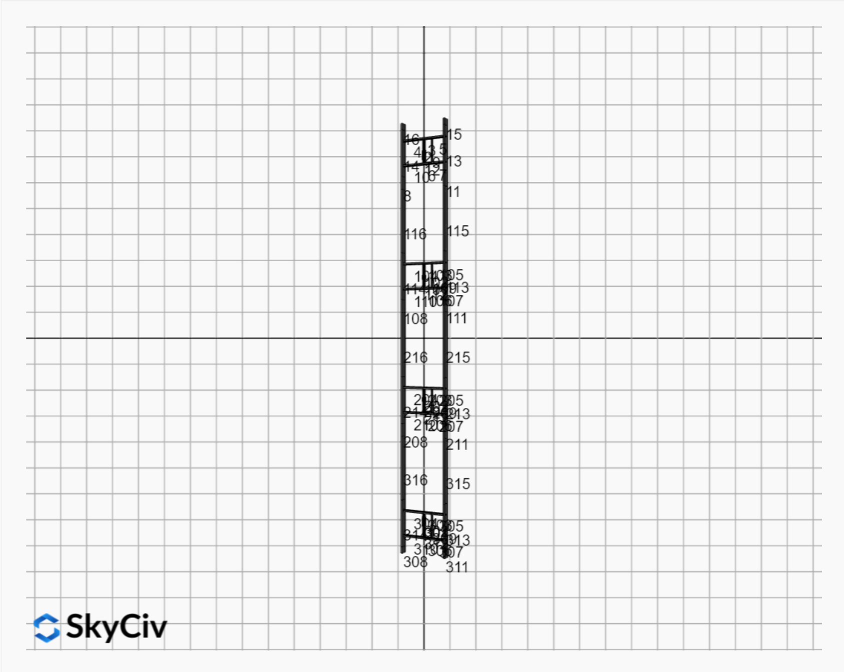
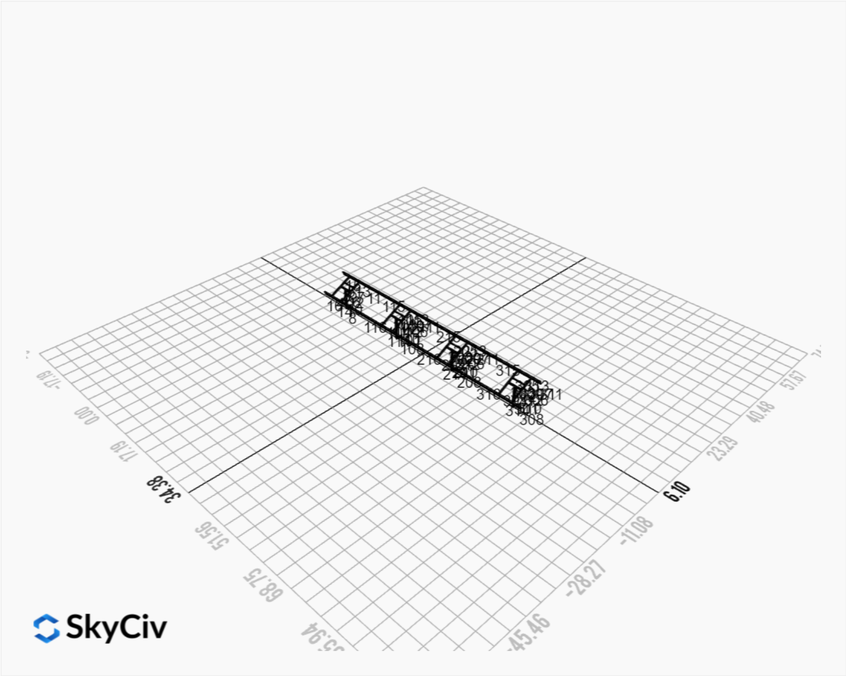
Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only

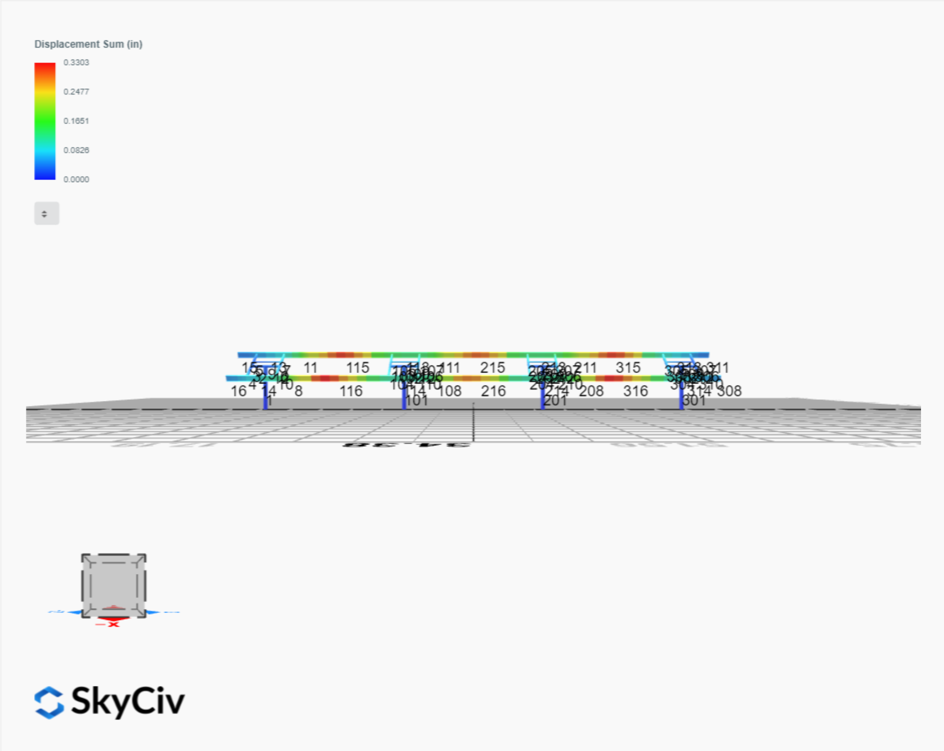


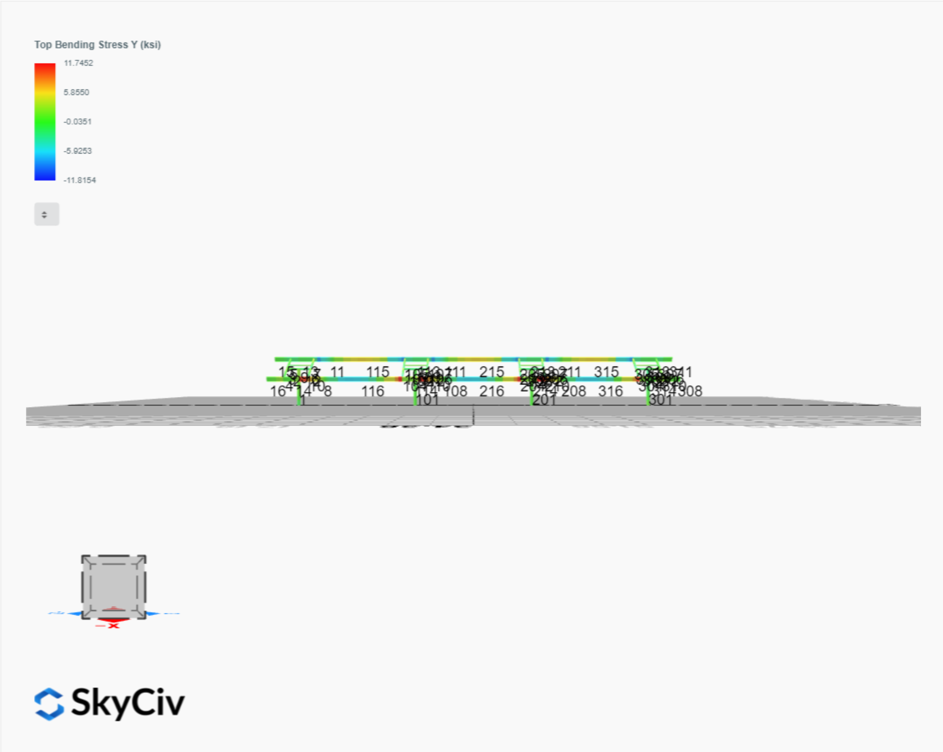


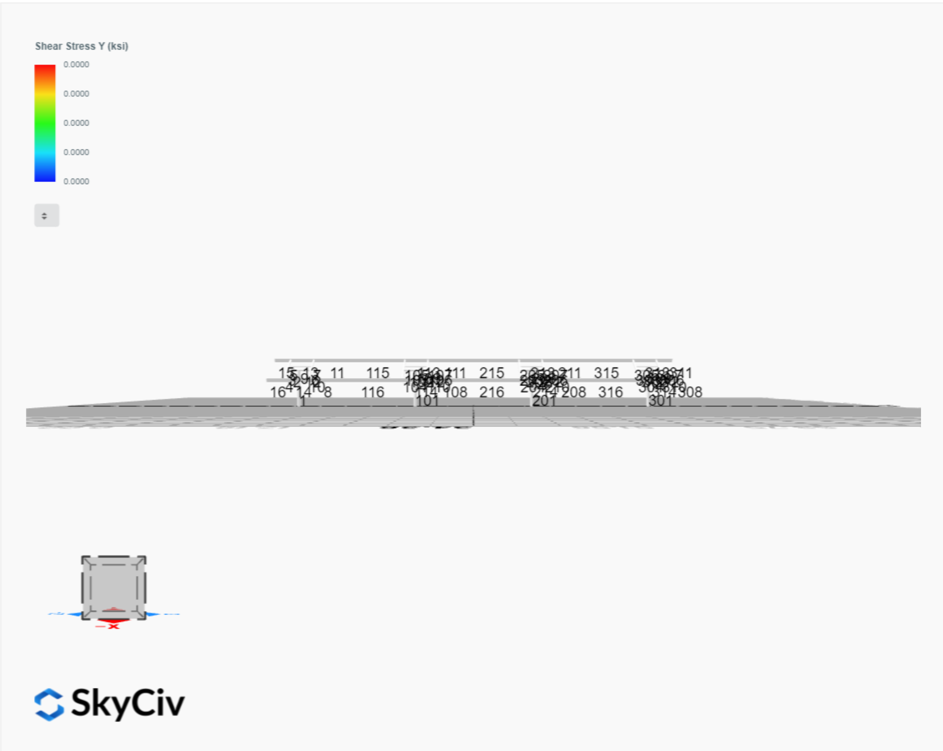


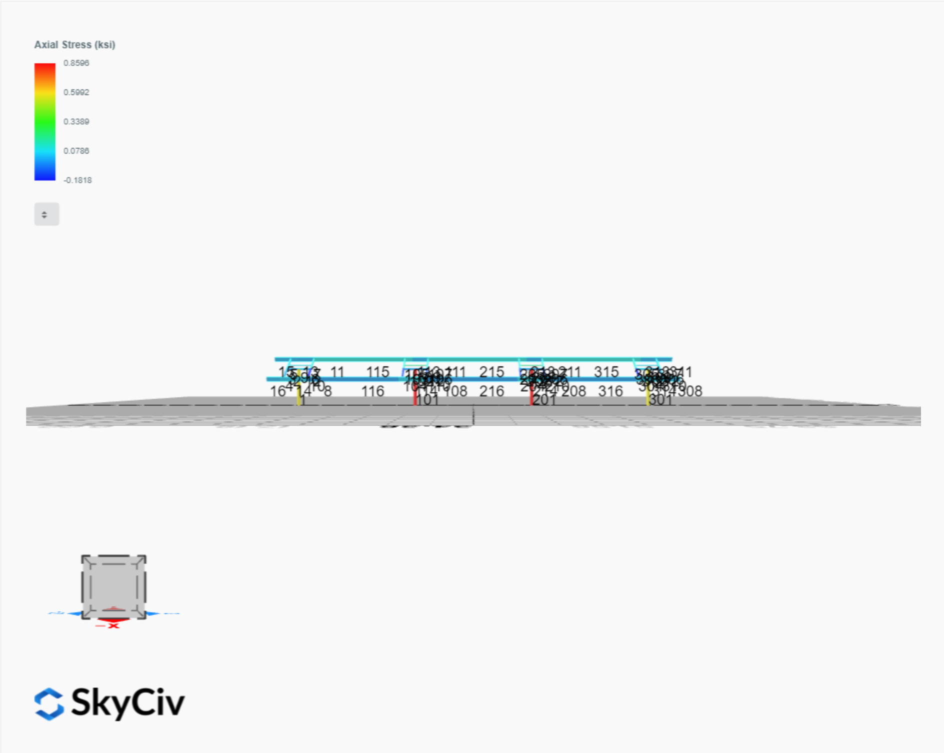


FEM Results (Envelope Worst Case for each member)




Top Bending Stress Y (ksi)
11.7452
5.8550
-0.0351
-5.9253
-11.8154


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000



Axial Stress (ksi)
0.8596
0.5992
0.3389
0.0786
-0.1818
SkyCiv

Reaction Forces for Foundation 1 (Node ID#1), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0333	1.6220	0.1131	0.1708	-0.0373	-0.1552
ULS: 2. D + L	0.0333	1.6220	0.1131	0.1708	-0.0373	-0.1552
ULS: 3. D + (S or Lr or R)	0.1207	4.8573	0.4109	0.6214	-0.1359	-0.6324
ULS: 3. D + (S or Lr or R)	0.0333	1.6220	0.1131	0.1708	-0.0373	-0.1552
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0988	4.0485	0.3364	0.5088	-0.1113	-0.5131
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0333	1.6220	0.1131	0.1708	-0.0373	-0.1552
ULS: 5b. D + 0.7E	0.0333	1.6220	0.1131	0.1708	-0.0373	-0.1552
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0988	4.0485	0.3364	0.5088	-0.1113	-0.5131
ULS: 8. 0.6D + 0.7E	0.0200	0.9732	0.0678	0.1025	-0.0224	-0.0931
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.6996	4.9784	0.4805	0.6894	-0.4557	11.0486
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.6996	4.9784	0.4805	0.6894	-0.4557	11.0486
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5342	-1.2877	-0.1999	-0.2708	0.3193	-9.3358
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.3334	-0.8597	-0.1938	-0.2606	0.3227	-15.9866
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2009	6.5658	0.6120	0.8977	-0.4251	7.8898
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2009	6.5658	0.6120	0.8977	-0.4251	7.8898
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2245	1.8662	0.1017	0.1776	0.1562	-7.3985
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0739	2.1873	0.1063	0.1853	0.1588	-12.3866
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2664	4.1393	0.3887	0.5597	-0.3511	8.2476
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2664	4.1393	0.3887	0.5597	-0.3511	8.2476
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1590	-0.5603	-0.1217	-0.1604	0.2301	-7.0406
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0084	-0.2392	-0.1171	-0.1527	0.2327	-12.0287
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.7129	4.3296	0.4353	0.6211	-0.4408	11.1107
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.7129	4.3296	0.4353	0.6211	-0.4408	11.1107
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5209	-1.9365	-0.2451	-0.3391	0.3342	-9.2737
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.3201	-1.5084	-0.2390	-0.3289	0.3377	-15.9245

Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundatino Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	9.9199
Shear X	-2.8882
Shear Z	0.9232
Moment X	1.3675
Moment Y (Twist)	0.7939
Moment Z	27.1000

Worst Case Reactions ASD

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	6.5658
Shear X	-1.7129
Shear Z	0.6120
Moment X	0.8977
Moment Y (Twist)	0.4557
Moment Z	15.9866

Reaction Forces for Foundation 2 (Node ID#101), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0333	2.2177	-0.0130	-0.0201	0.0139	0.2154
ULS: 2. D + L	-0.0333	2.2177	-0.0130	-0.0201	0.0139	0.2154
ULS: 3. D + (S or Lr or R)	-0.1206	7.0152	-0.0472	-0.0731	0.0503	0.7227
ULS: 3. D + (S or Lr or R)	-0.0333	2.2177	-0.0130	-0.0201	0.0139	0.2154
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0988	5.8158	-0.0387	-0.0598	0.0412	0.5959
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0333	2.2177	-0.0130	-0.0201	0.0139	0.2154
ULS: 5b. D + 0.7E	-0.0333	2.2177	-0.0130	-0.0201	0.0139	0.2154

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0988	5.8158	-0.0387	-0.0598	0.0412	0.5959
ULS: 8. 0.6D + 0.7E	-0.0200	1.3306	-0.0078	-0.0121	0.0083	0.1293
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.5979	7.2956	-0.0405	-0.0648	0.0289	16.2379
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.5979	7.2956	-0.0405	-0.0648	0.0289	16.2379
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.1932	-2.1882	0.0129	0.0213	-0.0025	-12.8486
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.8239	-1.4974	-0.0134	-0.0156	0.0356	-21.2892
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0223	9.6243	-0.0593	-0.0933	0.0524	12.6127
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0223	9.6243	-0.0593	-0.0933	0.0524	12.6127
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5711	2.5115	-0.0192	-0.0287	0.0289	-9.2021
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2941	3.0296	-0.0389	-0.0564	0.0575	-15.5326
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9567	6.0261	-0.0337	-0.0536	0.0251	12.2323
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.9567	6.0261	-0.0337	-0.0536	0.0251	12.2323
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6366	-1.0867	0.0065	0.0110	0.0016	-9.5826
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3596	-0.5686	-0.0133	-0.0168	0.0302	-15.9130
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.5846	6.4085	-0.0353	-0.0567	0.0233	16.1517
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.5846	6.4085	-0.0353	-0.0567	0.0233	16.1517
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.2066	-3.0753	0.0182	0.0294	-0.0080	-12.9348
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.8372	-2.3844	-0.0082	-0.0076	0.0300	-21.3754

Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundatino Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	14.5690
Shear X	-4.3573
Shear Z	-0.0926
Moment X	-0.1454
Moment Y (Twist)	0.0963
Moment Z	35.8483

Worst Case Reactions ASD

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	9.6243
Shear X	-2.5979
Shear Z	-0.0593
Moment X	-0.0933
Moment Y (Twist)	0.0575
Moment Z	21.3754

Reaction Forces for Foundation 3 (Node ID#201), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0333	2.2177	0.0130	0.0201	-0.0138	0.2154
ULS: 2. D + L	-0.0333	2.2177	0.0130	0.0201	-0.0138	0.2154
ULS: 3. D + (S or Lr or R)	-0.1206	7.0152	0.0472	0.0730	-0.0501	0.7227
ULS: 3. D + (S or Lr or R)	-0.0333	2.2177	0.0130	0.0201	-0.0138	0.2154
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0988	5.8158	0.0387	0.0598	-0.0410	0.5959
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0333	2.2177	0.0130	0.0201	-0.0138	0.2154
ULS: 5b. D + 0.7E	-0.0333	2.2177	0.0130	0.0201	-0.0138	0.2154
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0988	5.8158	0.0387	0.0598	-0.0410	0.5959
ULS: 8. 0.6D + 0.7E	-0.0200	1.3306	0.0078	0.0121	-0.0083	0.1293
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.5979	7.2956	0.0405	0.0648	-0.0288	16.2379
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.5979	7.2956	0.0405	0.0648	-0.0288	16.2379
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.1933	-2.1882	-0.0129	-0.0213	0.0025	-12.8486
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.8239	-1.4974	0.0134	0.0156	-0.0356	-21.2892
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0223	9.6243	0.0593	0.0933	-0.0523	12.6127
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0223	9.6243	0.0593	0.0933	-0.0523	12.6127
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5711	2.5115	0.0192	0.0287	-0.0288	-9.2021
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2941	3.0296	0.0390	0.0564	-0.0573	-15.5326

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9567	6.0261	0.0337	0.0536	-0.0251	12.2323
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.9567	6.0261	0.0337	0.0536	-0.0251	12.2323
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6366	-1.0867	-0.0065	-0.0110	-0.0016	-9.5826
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3596	-0.5686	0.0133	0.0168	-0.0301	-15.9130
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.5846	6.4085	0.0353	0.0567	-0.0233	16.1517
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.5846	6.4085	0.0353	0.0567	-0.0233	16.1517
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.2066	-3.0753	-0.0182	-0.0294	0.0080	-12.9348
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.8372	-2.3844	0.0082	0.0076	-0.0300	-21.3754

Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundatino Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	14.5690
Shear X	-4.3573
Shear Z	0.0926
Moment X	0.1450
Moment Y (Twist)	0.0957
Moment Z	35.8483

Worst Case Reactions ASD

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	9.6243
Shear X	-2.5979
Shear Z	0.0593
Moment X	0.0933
Moment Y (Twist)	0.0573
Moment Z	21.3754

Reaction Forces for Foundation 4 (Node ID#301), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0333	1.6220	-0.1131	-0.1708	0.0373	-0.1552
ULS: 2. D + L	0.0333	1.6220	-0.1131	-0.1708	0.0373	-0.1552
ULS: 3. D + (S or Lr or R)	0.1206	4.8573	-0.4109	-0.6216	0.1361	-0.6323
ULS: 3. D + (S or Lr or R)	0.0333	1.6220	-0.1131	-0.1708	0.0373	-0.1552
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0988	4.0485	-0.3364	-0.5089	0.1114	-0.5130
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0333	1.6220	-0.1131	-0.1708	0.0373	-0.1552
ULS: 5b. D + 0.7E	0.0333	1.6220	-0.1131	-0.1708	0.0373	-0.1552
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0988	4.0485	-0.3364	-0.5089	0.1114	-0.5130
ULS: 8. 0.6D + 0.7E	0.0200	0.9732	-0.0678	-0.1025	0.0224	-0.0931
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.6996	4.9784	-0.4805	-0.6894	0.4558	11.0486
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.6996	4.9784	-0.4805	-0.6894	0.4558	11.0486
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5342	-1.2877	0.1999	0.2708	-0.3193	-9.3358
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.3334	-0.8597	0.1938	0.2606	-0.3227	-15.9866
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2009	6.5658	-0.6120	-0.8979	0.4253	7.8898
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2009	6.5658	-0.6120	-0.8979	0.4253	7.8898
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2245	1.8662	-0.1017	-0.1778	-0.1560	-7.3984
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0739	2.1872	-0.1063	-0.1854	-0.1586	-12.3865
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2664	4.1393	-0.3887	-0.5597	0.3512	8.2476
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2664	4.1393	-0.3887	-0.5597	0.3512	8.2476
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1590	-0.5603	0.1217	0.1604	-0.2301	-7.0406
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0084	-0.2392	0.1171	0.1527	-0.2327	-12.0287
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.7129	4.3296	-0.4353	-0.6211	0.4408	11.1107
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.7129	4.3296	-0.4353	-0.6211	0.4408	11.1107
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5209	-1.9365	0.2451	0.3391	-0.3342	-9.2737
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.3201	-1.5084	0.2390	0.3289	-0.3377	-15.9245

Worst Case Reactions LRFD

Worst Case Reactions ASD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundatino Module.
Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	9.9198
Shear X	-2.8882
Shear Z	-0.9232
Moment X	-1.3683
Moment Y (Twist)	0.7945
Moment Z	27.1007

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module.
Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	6.5658
Shear X	-1.7129
Shear Z	-0.6120
Moment X	-0.8979
Moment Y (Twist)	0.4558
Moment Z	15.9866

Project Details

Design Code: AISC 360-16 LRFD
Provision: LRFD
Country: United States

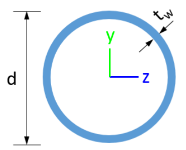
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

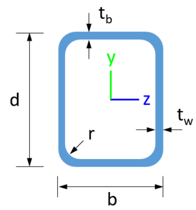
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

Design Materials			
ID	E (ksi)	F_y (ksi)	F_u (ksi)
1	29000	50	65

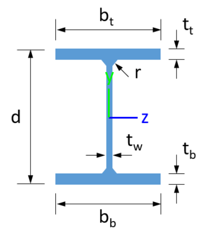
Section Dimensions



ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
7	6in Pipe Sch 40	6.63	0.28					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
17	HSS5x3x1/4	5.00	3.00	0.23	0.23	0.23		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
20	W10x12	9.87	0.19	3.96	3.96	0.21	0.21	0.30

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28

17	HSS5x3x1/4	3.37	11.00	4.81	10.70	62.42	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	12.91	12.91	6.15	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.17,1.17,1.17,1.18,1.19,1.18,1.18,1.15,1.16,1.17,1.17,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.70,1.69,1.70,1.68,1.69,1.70,1.67,1.67,1.65,1.69,1.67,1.67,1.65,1.81,1.67,1.67,1.68,1.68,1.68,1.68,1.63,1.72,1.67,1.67,1.66,2.58	300	200	1
5	17	1.52	1.52	2.33	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.68,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.20,1.19,1.20,1.19,1.19,1.20,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.19,1.19,1.19,1.19,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	1.20,1.20,1.20,1.20,1.20,1.19,1.19,1.18,2.04,1.19,1.19,1.19,1.16,1.20,1.20,1.22,1.24,1.19,1.19,1.18,2.09,1.19,1.19,1.19,1.06	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.91,1.67,1.67,1.68,1.68,1.68,1.68,1.64,1.72,1.67,1.67,1.66,1.50	300	200	1
11	20	1.33	1.33	2.05	1.22,1.22,1.22,1.22,1.22,1.23,1.23,1.25,1.33,1.24,1.24,1.24,1.30,1.23,1.23,1.20,1.12,1.23,1.23,1.25,1.33,1.24,1.24,1.24,1.30	300	200	1
12	6	4.20	4.20	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.78,1.81,1.78,1.82,1.79,1.78,1.65,1.65,1.47,1.42,1.62,1.62,1.60,1.44,1.73,1.73,2.01,3.30,1.65,1.65,1.50,1.42,1.62,1.62,1.61,1.44	300	200	1
14	20	4.88	4.00	7.50	1.91,1.96,1.91,1.99,1.94,1.91,2.20,2.20,2.58,1.90,2.23,2.23,2.36,2.64,2.10,2.10,1.77,1.59,2.17,2.17,2.62,1.89,2.24,2.24,2.33,2.96	300	200	1
15	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32	300	200	1
101	7	12.91	12.91	6.15	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.69,1.67,1.67,1.66,1.56,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.63	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1

108	20	1.33	1.33	2.05	2.35,2.35,2.35,2.35,2.35,2.35,2.31,2.31,2.28,1.27,2.31,2.31,2.30,1.01,2.33,2.33,2.39,2.09,2.31,2.31,2.28,1.25,2.30,2.30,2.30,1.09	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.69,1.67,1.67,1.66,1.30,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.71,1.67,1.67,1.66,1.61	300	200	1
111	20	1.33	1.33	2.05	2.15,2.16,2.15,2.15,2.16,2.15,2.07,2.07,1.77,1.49,2.07,2.07,2.05,1.61,2.09,2.09,2.30,1.47,2.07,2.07,1.80,1.50,2.07,2.07,2.06,1.63	300	200	1
112	6	4.20	4.20	2.00	-	300	200	1
113	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.09,1.17,1.07,1.07,1.08,1.10,1.07,1.07,1.06,1.04,1.07,1.07,1.08,1.17,1.07,1.07,1.08,1.10	300	200	1
114	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,2.52,1.06,1.06,1.06,1.03,1.06,1.06,1.06,1.07,1.06,1.06,1.07,2.05,1.06,1.06,1.06,1.04	300	200	1
115	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.14,1.12,1.09,1.13,1.13,1.13,1.10,1.14,1.14,1.18,1.33,1.14,1.14,1.12,1.09,1.13,1.13,1.13,1.11	300	200	1
116	20	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.18,1.19,1.07,1.18,1.18,1.18,2.22,1.17,1.17,1.16,1.14,1.18,1.18,1.19,1.07,1.18,1.18,1.18,2.24	300	200	1
201	7	12.91	12.91	6.15	-	300	200	1
202	6	4.20	4.20	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.69,1.67,1.67,1.66,1.31,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.71,1.67,1.67,1.66,1.61	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
208	20	1.33	1.33	2.05	2.03,2.04,2.03,2.05,2.03,2.03,2.08,2.08,2.09,1.16,2.08,2.08,2.08,1.15,2.07,2.07,1.94,1.72,2.08,2.08,2.09,1.14,2.08,2.08,2.08,1.26	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.69,1.67,1.67,1.66,1.56,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.63	300	200	1
211	20	1.33	1.33	2.05	1.85,1.85,1.85,1.85,1.85,1.85,1.65,1.65,1.47,1.34,1.62,1.62,1.56,1.40,1.73,1.73,2.08,2.08,1.65,1.65,1.48,1.35,1.62,1.62,1.58,1.41	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.09,1.17,1.07,1.07,1.08,1.10,1.07,1.07,1.06,1.04,1.07,1.07,1.08,1.17,1.07,1.07,1.08,1.10	300	200	1
214	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,2.52,1.06,1.06,1.06,1.03,1.06,1.06,1.06,1.07,1.06,1.06,1.07,2.06,1.06,1.06,1.06,1.04	300	200	1
215	20	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.15,1.13,1.11,1.15,1.15,1.14,1.12,1.16,1.16,1.20,2.64,1.15,1.15,1.13,1.11,1.15,1.15,1.14,1.12	300	200	1
216	20	6.63	6.63	10.20	1.18,1.19,1.18,1.19,1.19,1.18,1.19,1.19,1.21,1.08,1.20,1.20,1.20,1.03,1.19,1.19,1.18,1.16,1.19,1.19,1.21,1.08,1.20,1.20,1.20,1.29	300	200	1
301	7	12.91	12.91	6.15	-	300	200	1

302	6	4.20	4.20	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.20,1.19,1.20,1.19,1.19,1.20,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.19,1.19,1.19,1.19,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.91,1.67,1.67,1.68,1.68,1.68,1.68,1.64,1.72,1.67,1.67,1.66,1.50	300	200	1
305	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.17,1.17,1.17,1.18,1.19,1.18,1.18,1.15,1.16,1.17,1.17,1.17,1.17	300	200	1
307	17	1.52	1.52	2.33	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.68,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
308	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.70,1.68,1.70,1.68,1.69,1.70,1.67,1.67,1.65,1.69,1.67,1.67,1.65,1.81,1.67,1.67,1.68,1.68,1.68,1.68,1.63,1.72,1.67,1.67,1.66,2.62	300	200	1
311	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.78,1.81,1.78,1.82,1.79,1.78,1.65,1.65,1.47,1.42,1.62,1.62,1.60,1.44,1.73,1.73,2.01,3.30,1.65,1.65,1.50,1.42,1.62,1.62,1.61,1.44	300	200	1
314	20	4.88	4.00	7.50	1.91,1.96,1.91,1.99,1.94,1.91,2.20,2.20,2.58,1.90,2.23,2.23,2.36,2.64,2.10,2.10,1.77,1.59,2.17,2.17,2.62,1.89,2.24,2.24,2.33,2.96	300	200	1
315	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.07,1.07,1.09,1.07,1.07,1.07,1.08,1.07,1.07,1.08,1.10,1.07,1.07,1.07,1.09,1.07,1.07,1.07,1.08	300	200	1
316	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.18,1.07,1.07,1.07,2.19,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.20,1.07,1.07,1.07,1.86	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	251.16	177.34	42.30	42.30	75.35	75.35
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	142.47	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	142.47	46.90	6.46	56.26	44.91
12	251.01	229.64	27.16	27.16	75.30	75.30
13	159.30	116.35	43.40	6.46	56.26	44.91
14	159.30	116.35	46.90	6.46	56.26	44.91
15	159.30	137.23	46.90	6.46	56.26	44.91
16	159.30	137.23	46.90	6.46	56.26	44.91
101	251.16	177.34	42.30	42.30	75.35	75.35
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95

103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	142.47	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	142.47	46.90	6.46	56.26	44.91
112	251.01	229.64	27.16	27.16	75.30	75.30
113	159.30	116.35	31.78	6.46	56.26	44.91
114	159.30	116.35	31.48	6.46	56.26	44.91
115	159.30	75.13	20.99	6.46	56.26	44.91
116	159.30	75.13	20.61	6.46	56.26	44.91
201	251.16	177.34	42.30	42.30	75.35	75.35
202	251.01	229.64	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	142.47	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	142.47	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	116.35	31.78	6.46	56.26	44.91
214	159.30	116.35	31.48	6.46	56.26	44.91
215	159.30	75.13	21.38	6.46	56.26	44.91
216	159.30	75.13	19.84	6.46	56.26	44.91
301	251.16	177.34	42.30	42.30	75.35	75.35
302	251.01	229.64	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	137.23	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	137.23	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	116.35	43.40	6.46	56.26	44.91
314	159.30	116.35	46.90	6.46	56.26	44.91
315	159.30	75.13	20.61	6.46	56.26	44.91
316	159.30	75.13	20.61	6.46	56.26	44.91

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.056	0.641	0.101	0.038	0.012	0.649	#16	0.345	Not Required	Pass
2	0.002	0.215	0.086	0.051	0.018	0.286	#13	0.054	Not Required	Pass
3	0.004	0.357	0.018	0.035	0.008	0.376	#13	0.046	Not Required	Pass
4	0.003	0.352	0.060	0.035	0.013	0.413	#21	0.133	Not Required	Pass

4	0.003	0.352	0.060	0.035	0.013	0.413	#21	0.122	Not Required	Pass
5	0.004	0.221	0.014	0.035	0.004	0.233	#13	0.076	Not Required	Pass
6	0.007	0.512	0.097	0.053	0.027	0.606	#21	0.046	Not Required	Pass
7	0.008	0.317	0.132	0.051	0.035	0.351	#21	0.076	Not Required	Pass
8	0.003	0.126	0.136	0.029	0.015	0.184	#21	0.102	Not Required	Pass
9	0.004	0.048	0.078	0.002	0.005	0.116	#21	0.206	Not Required	Pass
10	0.009	0.482	0.115	0.048	0.025	0.525	#21	0.082	Not Required	Pass
11	0.007	0.121	0.142	0.032	0.015	0.187	#21	0.102	Not Required	Pass
12	0.002	0.373	0.115	0.079	0.022	0.471	#13	0.174	Not Required	Pass
13	0.009	0.059	0.353	0.042	0.019	0.364	#24	0.306	Not Required	Pass
14	0.003	0.069	0.345	0.040	0.019	0.360	#24	0.204	Not Required	Pass
15	0.000	0.004	0.008	0.006	0.002	0.012	#21	Not Required	Not Required	Pass
16	0.000	0.003	0.008	0.006	0.002	0.012	#21	Not Required	Not Required	Pass
101	0.082	0.847	0.010	0.058	0.001	0.856	#32	0.345	Not Required	Pass
102	0.002	0.451	0.161	0.097	0.029	0.588	#13	0.036	Not Required	Pass
103	0.007	0.644	0.049	0.064	0.007	0.696	#21	0.046	Not Required	Pass
104	0.008	0.650	0.124	0.065	0.026	0.732	#21	0.082	Not Required	Pass
105	0.007	0.399	0.133	0.064	0.035	0.434	#21	0.076	Not Required	Pass
106	0.007	0.636	0.044	0.064	0.006	0.679	#21	0.046	Not Required	Pass
107	0.007	0.395	0.125	0.063	0.032	0.426	#21	0.076	Not Required	Pass
108	0.004	0.047	0.130	0.036	0.015	0.175	#21	0.102	Not Required	Pass
109	0.012	0.058	0.040	0.001	0.000	0.102	#21	0.206	Not Required	Pass
110	0.007	0.629	0.124	0.063	0.027	0.718	#21	0.082	Not Required	Pass
111	0.007	0.053	0.133	0.036	0.015	0.168	#21	0.102	Not Required	Pass
112	0.003	0.435	0.159	0.095	0.029	0.573	#13	0.116	Not Required	Pass
113	0.009	0.191	0.357	0.051	0.019	0.515	#21	0.306	Not Required	Pass
114	0.006	0.219	0.356	0.052	0.020	0.537	#21	0.306	Not Required	Pass
115	0.013	0.339	0.188	0.041	0.015	0.531	#21	0.507	Not Required	Pass
116	0.005	0.323	0.189	0.042	0.015	0.508	#21	0.507	Not Required	Pass
201	0.082	0.847	0.010	0.058	0.001	0.856	#32	0.345	Not Required	Pass
202	0.003	0.435	0.159	0.095	0.029	0.573	#13	0.116	Not Required	Pass
203	0.007	0.636	0.044	0.064	0.006	0.679	#21	0.046	Not Required	Pass
204	0.007	0.629	0.124	0.063	0.027	0.718	#21	0.082	Not Required	Pass
205	0.007	0.395	0.125	0.063	0.032	0.426	#21	0.076	Not Required	Pass
206	0.007	0.644	0.049	0.064	0.007	0.696	#21	0.046	Not Required	Pass
207	0.007	0.399	0.133	0.064	0.035	0.434	#21	0.076	Not Required	Pass
208	0.003	0.063	0.144	0.042	0.015	0.170	#21	0.102	Not Required	Pass
209	0.012	0.058	0.040	0.001	0.000	0.102	#21	0.206	Not Required	Pass
210	0.008	0.650	0.124	0.065	0.026	0.732	#21	0.082	Not Required	Pass
211	0.007	0.080	0.146	0.041	0.015	0.160	#21	0.102	Not Required	Pass
212	0.002	0.451	0.161	0.097	0.029	0.588	#13	0.036	Not Required	Pass
213	0.009	0.191	0.358	0.051	0.019	0.515	#21	0.306	Not Required	Pass
214	0.006	0.219	0.356	0.052	0.020	0.537	#21	0.306	Not Required	Pass
215	0.012	0.219	0.189	0.036	0.015	0.405	#21	0.507	Not Required	Pass
216	0.005	0.176	0.186	0.036	0.015	0.361	#21	0.507	Not Required	Pass
301	0.056	0.641	0.101	0.038	0.012	0.649	#16	0.345	Not Required	Pass
302	0.002	0.373	0.115	0.079	0.022	0.471	#13	0.174	Not Required	Pass
303	0.007	0.512	0.097	0.053	0.027	0.606	#21	0.046	Not Required	Pass
304	0.009	0.482	0.115	0.048	0.025	0.525	#21	0.082	Not Required	Pass
305	0.008	0.317	0.132	0.051	0.035	0.351	#21	0.076	Not Required	Pass
306	0.004	0.357	0.018	0.035	0.008	0.376	#13	0.046	Not Required	Pass
307	0.004	0.221	0.014	0.035	0.004	0.233	#13	0.076	Not Required	Pass
308	0.000	0.003	0.008	0.006	0.002	0.012	#21	Not Required	Not Required	Pass
309	0.004	0.048	0.079	0.002	0.005	0.116	#21	0.206	Not Required	Pass

310	0.003	0.352	0.060	0.035	0.013	0.413	#21	0.122	Not Required	Pass
311	0.000	0.004	0.008	0.006	0.002	0.012	#21	Not Required	Not Required	Pass
312	0.002	0.215	0.086	0.051	0.018	0.286	#13	0.054	Not Required	Pass
313	0.009	0.059	0.353	0.042	0.019	0.364	#24	0.204	Not Required	Pass
314	0.003	0.069	0.345	0.040	0.019	0.360	#24	0.306	Not Required	Pass
315	0.013	0.362	0.188	0.032	0.015	0.548	#21	0.507	Not Required	Pass
316	0.005	0.352	0.187	0.030	0.015	0.534	#21	0.507	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/comression)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

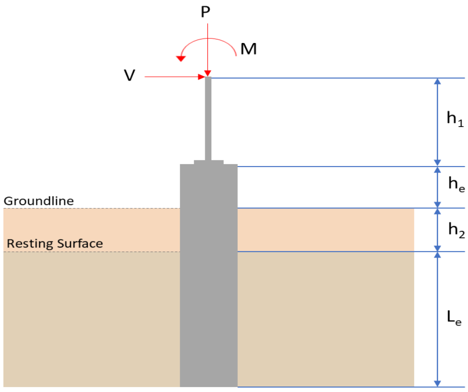
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 7.5 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.566	9.920
V_x (kip)	-1.713	-2.888
V_z (kip)	0.612	0.923
M_x (kipft)	0.898	1.368
M_z (kipft)	15.987	27.100

Material Properties

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$$

$$H = 0 \text{ ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{D}$$

$$H_o = \frac{(-1.713 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.571 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\, H)}{D}$$

$$M_o = \frac{(15.987 \text{ kipft}) + ((-1.713 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.329 \text{ kipft/ft}$$

Required depth of embedment in earth:

$$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,x} = 6.7437 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.612 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.204 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z H)}{D}$$

$$M_o = \frac{(0.898 \text{ kipft}) + ((0.612 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.29933 \text{ kipft/ft}$$

Required depth of embedment in earth:

$$L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,z} = 5.151 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

$L_{e,req}$ - Depth of pile required,

$$L_{e,req} = MAX[L_{e,x}, L_{e,z}]$$

$$L_{e,req} = MAX[(6.7437 \text{ ft}), (5.151 \text{ ft})]$$

$$L_{e,req} = 6.744 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

$Ratio$ - Embedded depth

$$Ratio = \frac{L_{e,req}}{L_e}$$

$$Ratio = \frac{(6.744 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.8992$$

Status: **PASS**
Ratio: **0.900**

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

$$q = \frac{P_v}{A}$$

$$q = \frac{(6.566 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.9289 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

$$Ratio = \frac{q}{q_a}$$

$$Ratio = \frac{(0.9289 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.46445$$

Status: **PASS**
Ratio: **0.460**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

$$L/D = \frac{L}{D}$$

$$L/D = \frac{(7.5 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.571 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 5.329 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (5.329 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.571 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (5.329 \text{ kipft/ft})) + (4 \times (-0.571 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.218 \text{ ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{1.178\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (5.329 \text{ kipft/ft})) + (3 \times (-0.571 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (5.329 \text{ kipft/ft})) + (2 \times (-0.571 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.20236 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (5.329 \text{ kipft/ft})) + ((-0.571 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 1.0683 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\, \frac{a}{2}$$

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.218 \text{ ft})}{2}$$

$$p_a = 0.39135 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{(0.20236 \text{ kip/ft}^2)}{(0.39135 \text{ kip/ft}^2)}$$

$$Ratio = 0.51707$$

Status: **PASS**
Ratio: **0.520**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.0683\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94956$$

Status: **PASS**
Ratio: **0.950**

Considering z-direction:

$H_o = 0.204\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.29933\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$

$$a = \frac{(4 \times (0.29933\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.204\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.29933\ \mathrm{kipft/ft})) + (4 \times (0.204\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.4832\ \mathrm{ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.29933\ \mathrm{kipft/ft})) + (3 \times (0.204\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.29933\ \mathrm{kipft/ft})) + (2 \times (0.204\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.17722\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.29933\ \mathrm{kipft/ft})) + ((0.204\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.35667\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\,\frac{a}{2}$$

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.4832\ \mathrm{ft})}{2}$$

$$p_a = 0.41124\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{\left(0.17722\ \mathrm{kip/ft^2}\right)}{\left(0.41124\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.43093$$

Status: **PASS**
Ratio: **0.430**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

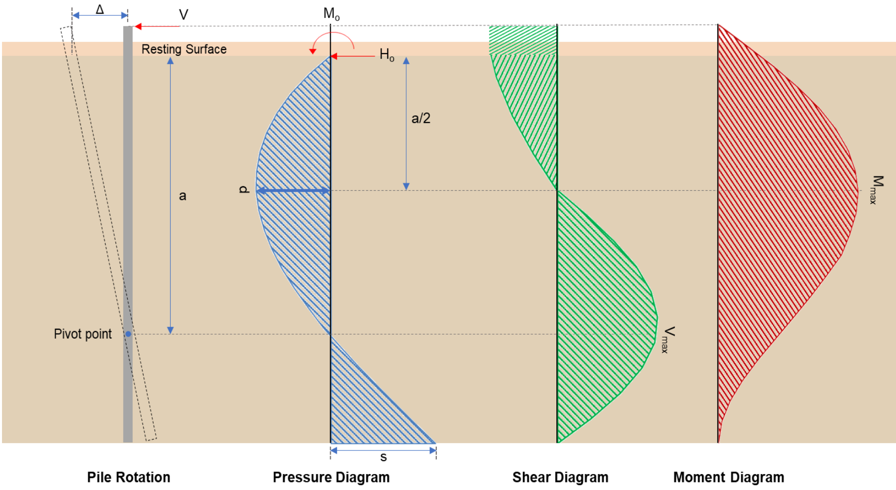
$Ratio$ - Lateral soil capacity

$$Ratio = \frac{}{p_s}$$

$$Ratio = \frac{(0.35667\ \mathrm{kip/ft^2})}{(1.125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.31704$$

Status: **PASS**
Ratio: **0.320**



Shear force and Bending moment (x-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{D}$$

$$H_o = \frac{(-2.888\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.96267\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\ H)}{D}$$

$$M_o = \frac{(27.1\ \mathrm{kipft}) + ((-2.888\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 9.0333\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(9.0333\ \mathrm{kipft/ft})}{(-0.96267\ \mathrm{kip/ft})}$$

$$E = 9.3837\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\ M_o\ L_e) + \left(3\ H_o\ L_e^2\right)}{(6\ M_o) + (4\ H_o\ L_e)}$$

$$a = \frac{(4 \times (9.0333\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.96267\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (9.0333\ \mathrm{kipft/ft})) + (4 \times (-0.96267\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2173\ \mathrm{ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\ D)\left[1 - \left[3\left(\frac{4\ E}{L_e} + 3\right)\left(\frac{a}{L_e}\right)^2\right] + \left[4\left(\frac{3\ E}{L_e} + 2\right)\left(\frac{a}{L_e}\right)^3\right]\right]$$

$$V_{max} = ((-0.96267\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.3837\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.2173\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.3837\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.2173\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.2987 \text{ kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\,D\,L_e)\left[\left(\frac{E}{L_e} + \frac{a}{2\,L_e}\right) - \left[\left(\frac{4\,E}{L_e} + 3\right)\left(\frac{a}{2\,L_e}\right)^3\right] + \left[\left(\frac{3\,E}{L_e} + 2\right)\left(\frac{a}{2\,L_e}\right)^4\right]\right]$$

$$M_{max} = ((-0.96267 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(9.3837 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.2173 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (9.3837 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.2173 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.3837 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.2173 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 29.162 \text{ kipft}$$

Shear force and Bending moment (z-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.923 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.30767 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\,H)}{D}$$

$$M_o = \frac{(1.368 \text{ kipft}) + ((0.923 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.456 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(0.456 \text{ kipft/ft})}{(0.30767 \text{ kip/ft})}$$

$$E = 1.4821 \text{ ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$

$$a = \frac{(4 \times (0.456 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (0.30767 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.456 \text{ kipft/ft})) + (4 \times (0.30767 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.4821 \text{ ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\,b)\left[1 - \left[3\left(\frac{4\,E}{L_e} + 3\right)\left(\frac{a}{L_e}\right)^2\right] + \left[4\left(\frac{3\,E}{L_e} + 2\right)\left(\frac{a}{L_e}\right)^3\right]\right]$$

$$V_{max} = ((0.30767 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.4821 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.4821 \text{ ft})}{(7.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.4821 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.4821 \text{ ft})}{(7.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.94624 \text{ kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\,b\,L_e)\left[\left(\frac{E}{L_e} + \frac{a}{2\,L_e}\right) - \left[\left(\frac{4\,E}{L_e} + 3\right)\left(\frac{a}{2\,L_e}\right)^3\right] + \left[\left(\frac{3\,E}{L_e} + 2\right)\left(\frac{a}{2\,L_e}\right)^4\right]\right]$$

$$M_{max} = ((0.30767 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(1.4821 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.4821 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (1.4821 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.4821 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.4821 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.4821 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 2.9373 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

Required reinforcement due to axial load, $A_{st,required}$
22.4.2.2, 10.6.1.1 $A_{st,required}$

$$A_{st,required} = Min\left[\frac{\frac{P}{\phi\ \alpha} - \left(0.85\ f'_{ck}\ A_g\right)}{f_{yk} - \left(0.85\ f'_{ck}\right)}, \left(0.08\ A_g\right)\right]$$

$$A_{st,required} = Min\left[\frac{\frac{(9.92 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.063 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

$$A_{min} = Max\left[A_{st,required}, \left(0.0018\ A_g\right)\right]$$

$$A_{min} = Max\left[\left(-37.063 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

$$n_{rebar} = \frac{A_{min}}{A_{rebar}}$$

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

$$A_{st} = n_{rebar}\ \frac{\pi\ d_{bar}^2}{4}$$

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

$$Ratio = \frac{A_{min}}{A_{st}}$$

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

$$s_{rebar} = Max\left[1.5, \left(1.5\ d_{bar}\right)\right]$$

$$s_{rebar} = Max\left[1.5, (1.5 \times (0.625 \text{ in}))\right]$$

$$s_{rebar} = 1.5 \text{ in}$$

Ties:

25.7.2.2 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)
25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

$$s_{ties} = Min\left[\left(16\ d_{bar}\right), \left(48\ d_{ties}\right), D\right]$$

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

$$s_{ties} = 10 \text{ in}$$

Summary:

	Main reinforcement: **6 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

$$\phi P_N = \phi\, 0.85\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

$$Ratio = \frac{P}{\phi P_N}$$

$$Ratio = \frac{(9.92\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0079112$$

Status: **PASS**
Ratio: **0.010**

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,

22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

$$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 9.92\ \text{kip} \rightarrow 9920\ \text{lbf}$,

22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

$$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right] b_w\, d$$

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(9920\ \text{lbf})}{6 \times \left(1017.9\ \text{in}^2\right)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.122\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,

22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

$$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right] b_w\, d$$

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

$$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$

$$V_c = Min\left[(186.09\ \text{kip}), (76.122\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.122 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

$$V_{s,a} = 8 \sqrt{f'_{ck}}\, b_w\, d$$

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi\, d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$

$$A_v = 0.11045 \text{ in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

V_s - Governing shear strength of steel

$$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$

$$V_s = MIN\left[(414.72 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\ (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((76.122 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.29 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.2987 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(8.2987 \text{ kip})}{(74.29 \text{ kip})}$$

$$Ratio = 0.11171$$

Status: **PASS**
Ratio: **0.110**

Considering z-direction:

$V_{max} = 0.94624 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(0.94624 \text{ kip})}{(74.29 \text{ kip})}$$

$$Ratio = 0.012737$$

Status: **PASS**
Ratio: **0.010**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

	$$S_m = 4580.4\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442 in^3$$ $$\phi M_{n,1} = 62.027 kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$ $$\phi M_n = 62.027\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 29.162\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(29.162\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.47015$$	Status: **PASS** Ratio: **0.470**
	Considering z-direction: $M_{max} = 2.9373\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(2.9373\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.047355$$	Status: **PASS** Ratio: **0.050**

REFERENCES	CALCULATIONS	RESULTS

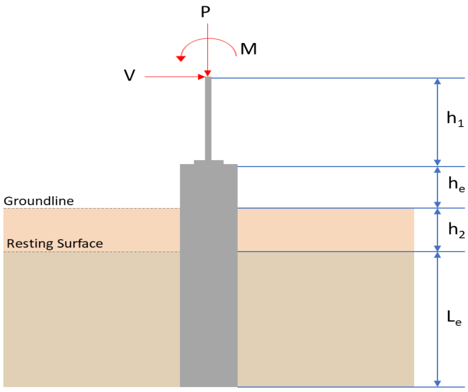
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: round
$D = 36$ in - Pile diameter
$L = 7.5$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.566	9.920
V_x (kip)	-1.713	-2.888
V_z (kip)	-0.612	-0.923
M_x (kipft)	-0.898	-1.368
M_z (kipft)	15.987	27.101

Material Properties

$f'_{ck} = 2.5$ ksi - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$$

$$H = 0 \text{ ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{D}$$

$$H_o = \frac{(-1.713 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.571 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\ H)}{D}$$

$$M_o = \frac{(15.987 \text{ kipft}) + ((-1.713 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.329 \text{ kipft/ft}$$

Required depth of embedment in earth:

$$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,x} = 6.7437 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.612 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.204 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z H)}{D}$$

$$M_o = \frac{(0.898 \text{ kipft}) + ((-0.612 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.29933 \text{ kipft/ft}$$

Required depth of embedment in earth:

$$L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,z} = 1.7004 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

$L_{e,req}$ - Depth of pile required,

$$L_{e,req} = MAX[L_{e,x}, L_{e,z}]$$

$$L_{e,req} = MAX[(6.7437 \text{ ft}), (1.7004 \text{ ft})]$$

$$L_{e,req} = 6.744 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

$Ratio$ - Embedded depth

$$Ratio = \frac{L_{e,req}}{L_e}$$

$$Ratio = \frac{(6.744 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.8992$$

Status: **PASS**
Ratio: **0.900**

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

$$q = \frac{P_v}{A}$$

$$q = \frac{(6.566 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.9289\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

$$Ratio = \frac{q}{q_a}$$

$$Ratio = \frac{(0.9289\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.46445$$

Status: **PASS**
Ratio: **0.460**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

$$L/D = \frac{L}{D}$$

$$L/D = \frac{(7.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.571\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.329\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + (3\, H_o\, L_e^2)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (5.329\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.571\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (5.329\ \mathrm{kipft/ft})) + (4 \times (-0.571\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.218\ \mathrm{ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{1.178\ [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\ [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (5.329\ \mathrm{kipft/ft})) + (3 \times (-0.571\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (5.329\ \mathrm{kipft/ft})) + (2 \times (-0.571\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.20236\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (5.329\ \mathrm{kipft/ft})) + ((-0.571\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.0683\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\, \frac{a}{2}$$

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.218\ \mathrm{ft})}{2}$$

$$p_a = 0.39135\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{(0.20236\ \mathrm{kip/ft^2})}{(0.39135\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.51707$$

Status: **PASS**
Ratio: **0.520**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.0683\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94956$$

Status: **PASS**
Ratio: **0.950**

Considering z-direction:

$H_o = -0.204\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.29933\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (0.29933\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.204\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.29933\ \mathrm{kipft/ft})) + (4 \times (-0.204\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.4832\ \mathrm{ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{1.178\ [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\ [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.29933\ \mathrm{kipft/ft})) + (3 \times (-0.204\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.29933\ \mathrm{kipft/ft})) + (2 \times (-0.204\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = -0.11149\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.29933\ \mathrm{kipft/ft})) + ((-0.204\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = -0.15605\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\, \frac{a}{2}$$

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.4832\ \mathrm{ft})}{2}$$

$$p_a = 0.41124\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{\left(-0.11149\ \mathrm{kip/ft^2}\right)}{\left(0.41124\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.27112$$

Status: **PASS**
Ratio: **-0.270**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

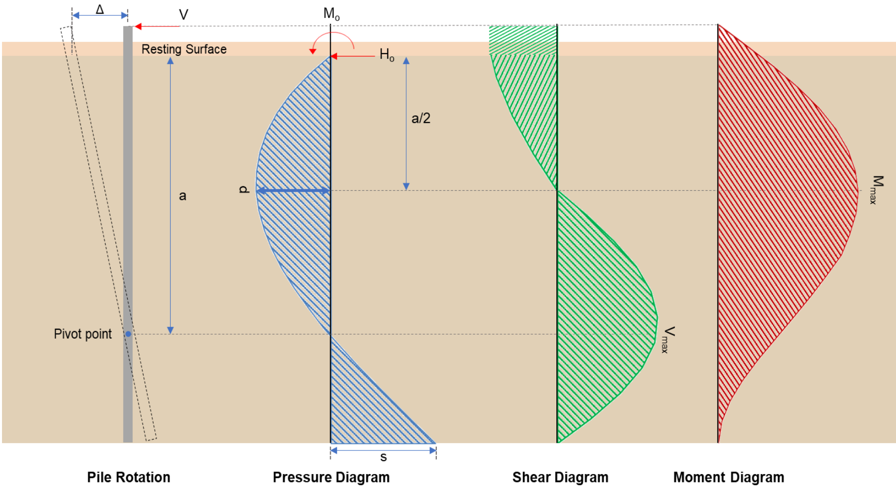
$$Ratio = \frac{s}{\ }$$

$$Ratio = \frac{}{p_s}$$

$$Ratio = \frac{(-0.15605\ \mathrm{kip/ft^2})}{(1.125\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.13871$$

Status: **PASS**
Ratio: **-0.140**



Shear force and Bending moment (x-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{D}$$

$$H_o = \frac{(-2.888\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.96267\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\, H)}{D}$$

$$M_o = \frac{(27.101\ \mathrm{kipft}) + ((-2.888\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 9.0337\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(9.0337\ \mathrm{kipft/ft})}{(-0.96267\ \mathrm{kip/ft})}$$

$$E = 9.384\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + (3\, H_o\, L_e^2)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (9.0337\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.96267\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (9.0337\ \mathrm{kipft/ft})) + (4 \times (-0.96267\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2173\ \mathrm{ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\, D) \left[1 - \left[3 \left(\frac{4\,E}{L_e} + 3\right) \left(\frac{a}{L_e}\right)^2\right] + \left[4 \left(\frac{3\,E}{L_e} + 2\right) \left(\frac{a}{L_e}\right)^3\right]\right]$$

$$V_{max} = ((-0.96267\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.384\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.2173\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.384\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.2173\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.2989\ \text{kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\, D\, L_e)\left[\left(\frac{E}{L_e} + \frac{a}{2\, L_e}\right) - \left[\left(\frac{4\, E}{L_e} + 3\right)\left(\frac{a}{2\, L_e}\right)^3\right] + \left[\left(\frac{3\, E}{L_e} + 2\right)\left(\frac{a}{2\, L_e}\right)^4\right]\right]$$

$$M_{max} = ((-0.96267\ \text{kip/ft}) \times (36\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(9.384\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.2173\ \text{ft})}{2 \times (7.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (9.384\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.2173\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.384\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.2173\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 29.163\ \text{kipft}$$

Shear force and Bending moment (z-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.923\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.30767\ \text{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{D}$$

$$M_o = \frac{(1.368\ \text{kipft}) + ((-0.923\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.456\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(0.456\ \text{kipft/ft})}{(-0.30767\ \text{kip/ft})}$$

$$E = 1.4821\ \text{ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (0.456\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.30767\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (0.456\ \text{kipft/ft})) + (4 \times (-0.30767\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.4821\ \text{ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\, b)\left[1 - \left[3\left(\frac{4\, E}{L_e} + 3\right)\left(\frac{a}{L_e}\right)^2\right] + \left[4\left(\frac{3\, E}{L_e} + 2\right)\left(\frac{a}{L_e}\right)^3\right]\right]$$

$$V_{max} = ((-0.30767\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.4821\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.4821\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.4821\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.4821\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.94624\ \text{kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\, b\, L_e)\left[\left(\frac{E}{L_e} + \frac{a}{2\, L_e}\right) - \left[\left(\frac{4\, E}{L_e} + 3\right)\left(\frac{a}{2\, L_e}\right)^3\right] + \left[\left(\frac{3\, E}{L_e} + 2\right)\left(\frac{a}{2\, L_e}\right)^4\right]\right]$$

$$M_{max} = ((-0.30767\ \text{kip/ft}) \times (36\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(1.4821\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.4821\ \text{ft})}{2 \times (7.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (1.4821\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.4821\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.4821\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.4821\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.9373 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

Required reinforcement due to axial load, $A_{st,required}$
22.4.2.2, 10.6.1.1 $A_{st,required}$

$$A_{st,required} = Min\left[\frac{\frac{P}{\phi\ \alpha} - \left(0.85\ f'_{ck}\ A_g\right)}{f_{yk} - \left(0.85\ f'_{ck}\right)}, \left(0.08\ A_g\right)\right]$$

$$A_{st,required} = Min\left[\frac{\frac{(9.92 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.063 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

$$A_{min} = Max\left[A_{st,required}, \left(0.0018\ A_g\right)\right]$$

$$A_{min} = Max\left[\left(-37.063 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

$$n_{rebar} = \frac{A_{min}}{A_{rebar}}$$

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

$$A_{st} = n_{rebar}\ \frac{\pi\ d_{bar}^2}{4}$$

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

$$Ratio = \frac{A_{min}}{A_{st}}$$

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

$$s_{rebar} = Max\left[1.5, \left(1.5\ d_{bar}\right)\right]$$

$$s_{rebar} = Max\left[1.5, (1.5 \times (0.625 \text{ in}))\right]$$

$$s_{rebar} = 1.5 \text{ in}$$

Ties:

25.7.2.2 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)
25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

$$s_{ties} = Min\left[\left(16\ d_{bar}\right), \left(48\ d_{ties}\right), D\right]$$

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

$$s_{ties} = 10 \text{ in}$$

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

$$\phi P_N = \phi\, 0.85\ \left[\left(0.85\, f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

$$Ratio = \frac{P}{\phi P_N}$$

$$Ratio = \frac{(9.92\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0079112$$

Status: **PASS**
Ratio: **0.010**

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

$$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 9.92\ \text{kip} \rightarrow 9920\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

$$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(9920\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.122\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,
22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

$$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

$$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$

$$V_c = Min\left[(186.09\ \text{kip}), (76.122\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.122 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \to 2500 \text{ psi}$,

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

$$V_{s,a} = 8 \sqrt{f'_{ck}}\, b_w\, d$$

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi\, d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$

$$A_v = 0.11045 \text{ in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

V_s - Governing shear strength of steel

$$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$

$$V_s = MIN\left[(414.72 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\ (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((76.122 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.29 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.2989 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(8.2989 \text{ kip})}{(74.29 \text{ kip})}$$

$$Ratio = 0.11171$$

Status: **PASS**
Ratio: **0.110**

Considering z-direction:

$V_{max} = 0.94624 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(0.94624 \text{ kip})}{(74.29 \text{ kip})}$$

$$Ratio = 0.012737$$

Status: **PASS**
Ratio: **0.010**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

	$S_m = 4580.4 \text{ in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi \, 0.85 \, f_{ck}' \, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$ $$\phi M_{n,2} = 527.23 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$ $$\phi M_n = 62.027 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 29.163 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(29.163 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.47017$$	Status: **PASS** Ratio: **0.470**
	Considering z-direction: $M_{max} = 2.9373 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(2.9373 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.047355$$	Status: **PASS** Ratio: **0.050**

REFERENCES	CALCULATIONS	RESULTS

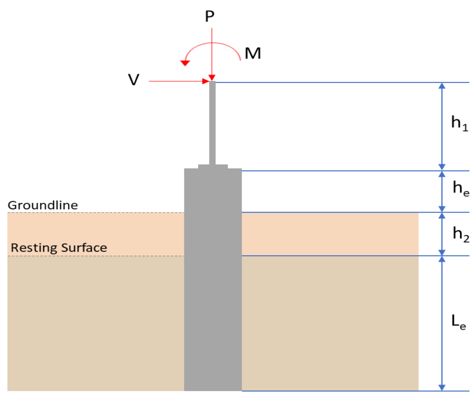
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: round

$D = 36\ \text{in}$ - Pile diameter

$L = 8\ \text{ft}$ - Total pile length

$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,

$h_2 = 0\ \text{ft}$ - Depth to resisting surface

$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	9.624	14.569
V_x (kip)	-2.598	-4.357
V_z (kip)	-0.059	-0.093
M_x (kipft)	-0.093	-0.145
M_z (kipft)	21.375	35.848

Material Properties

$f'_{ck} = 2.5\ \text{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0\ \text{ft}) + (0\ \text{ft}) + (0\ \text{ft})$$

$$H = 0\ \text{ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{D}$$

$$H_o = \frac{(-2.598\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.866\ \text{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\ H)}{D}$$

$$M_o = \frac{(21.375\ \mathrm{kipft}) + ((-2.598\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 7.125\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

$$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,x} = 6.9159\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.059\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.019667\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{D}$$

$$M_o = \frac{(0.093\ \mathrm{kipft}) + ((-0.059\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 0.031\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

$$L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,z} = 1.1907\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

$L_{e,req}$ - Depth of pile required,

$$L_{e,req} = MAX[L_{e,x}, L_{e,z}]$$

$$L_{e,req} = MAX[(6.9159\ \mathrm{ft}), (1.1907\ \mathrm{ft})]$$

$$L_{e,req} = 6.916\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8\ \mathrm{ft}$$

$Ratio$ - Embedded depth

$$Ratio = \frac{L_{e,req}}{L_e}$$

$$Ratio = \frac{(6.916\ \mathrm{ft})}{(8\ \mathrm{ft})}$$

$$Ratio = 0.8645$$

Status: **PASS**
Ratio: **0.860**

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi\left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \mathrm{in})}{2}\right)^2$$

$$A = 7.0686\ \mathrm{ft}^2$$

q - End-bearing pressure

$$q = \frac{P_v}{A}$$

$$q = \frac{(9.624\ \mathrm{kip})}{(7.0686\ \mathrm{ft}^2)}$$

$$q = 1.3615 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

$$Ratio = \frac{q}{q_a}$$

$$Ratio = \frac{\left(1.3615 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.68076$$

Status: **PASS**
Ratio: **0.680**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

$$L/D = \frac{L}{D}$$

$$L/D = \frac{(8 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.6667$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.866 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.125 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (7.125 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (-0.866 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (7.125 \text{ kipft/ft})) + (4 \times (-0.866 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.5955 \text{ ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{1.178\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (7.125 \text{ kipft/ft})) + (3 \times (-0.866 \text{ kip/ft}) \times (8 \text{ ft}))]^2}{(8 \text{ ft})^2 \times [(3 \times (7.125 \text{ kipft/ft})) + (2 \times (-0.866 \text{ kip/ft}) \times (8 \text{ ft}))]}$$

$$p = 0.14574 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (7.125 \text{ kipft/ft})) + ((-0.866 \text{ kip/ft}) \times (8 \text{ ft}))]}{(8 \text{ ft})^2}$$

$$s = 1.0783 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\, \frac{a}{2}$$

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5955 \text{ ft})}{2}$$

$$p_a = 0.41966 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{\left(0.14574 \text{ kip/ft}^2\right)}{\left(0.41966 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.34729$$

Status: **PASS**
Ratio: **0.350**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.0783\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.89857$$

Status: **PASS**
Ratio: **0.900**

Considering z-direction:

$H_o = -0.019667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.031\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$

$$a = \frac{(4 \times (0.031\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.019667\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.031\ \mathrm{kipft/ft})) + (4 \times (-0.019667\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.8479\ \mathrm{ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.031\ \mathrm{kipft/ft})) + (3 \times (-0.019667\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\ 2}}{(8\ \mathrm{ft})^2 \times [(3 \times (0.031\ \mathrm{kipft/ft})) + (2 \times (-0.019667\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = -0.010056\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.031\ \mathrm{kipft/ft})) + ((-0.019667\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = -0.014039\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\,\frac{a}{2}$$

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8479\ \mathrm{ft})}{2}$$

$$p_a = 0.43859\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{\left(-0.010056\ \mathrm{kip/ft^2}\right)}{\left(0.43859\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.022928$$

Status: **PASS**
Ratio: **-0.020**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

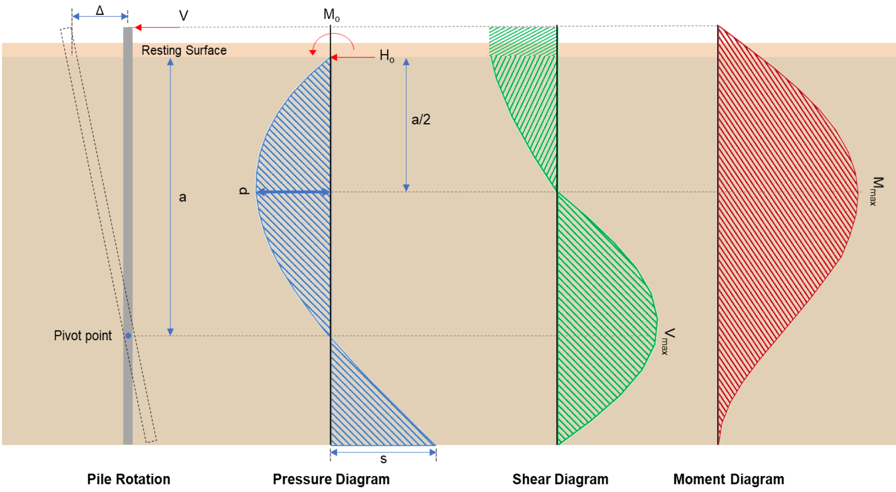
$$Ratio = \frac{s}{\ }$$

$$Ratio = \frac{}{p_s}$$

$$Ratio = \frac{\left(-0.014039 \text{ kip/ft}^2\right)}{\left(1.2 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.011699$$

Status: **PASS**
Ratio: **-0.010**



Shear force and Bending moment (x-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{D}$$

$$H_o = \frac{(-4.357 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.4523 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\, H)}{D}$$

$$M_o = \frac{(35.848 \text{ kipft}) + ((-4.357 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 11.949 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(11.949 \text{ kipft/ft})}{(-1.4523 \text{ kip/ft})}$$

$$E = 8.2277 \text{ ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (11.949 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (-1.4523 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (11.949 \text{ kipft/ft})) + (4 \times (-1.4523 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.5955 \text{ ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\, D) \left[1 - \left[3 \left(\frac{4\, E}{L_e} + 3\right) \left(\frac{a}{L_e}\right)^2\right] + \left[4 \left(\frac{3\, E}{L_e} + 2\right) \left(\frac{a}{L_e}\right)^3\right]\right]$$

$$V_{max} = ((-1.4523 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.2277 \text{ ft})}{(8 \text{ ft})} + 3\right) \times \left(\frac{(5.5955 \text{ ft})}{(8 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.2277 \text{ ft})}{(8 \text{ ft})} + 2\right) \times \left(\frac{(5.5955 \text{ ft})}{(8 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 10.806 \text{ kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\, D\, L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2\, L_e}\right) - \left[\left(\frac{4\, E}{L_e} + 3\right) \left(\frac{a}{2\, L_e}\right)^3\right] + \left[\left(\frac{3\, E}{L_e} + 2\right) \left(\frac{a}{2\, L_e}\right)^4\right]\right]$$

$$M_{max} = ((-1.4523 \text{ kip/ft}) \times (36 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(8.2277 \text{ ft})}{(8 \text{ ft})} + \frac{(5.5955 \text{ ft})}{2 \times (8 \text{ ft})}\right) - \left[\left(\frac{4 \times (8.2277 \text{ ft})}{(8 \text{ ft})} + 3\right) \times \left(\frac{(5.5955 \text{ ft})}{2 \times (8 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (8.2277 \text{ ft})}{(8 \text{ ft})} + 2\right) \times \left(\frac{(5.5955 \text{ ft})}{2 \times (8 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 40.083 \text{ kipft}$$

Shear force and Bending moment (z-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.093 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.031 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{D}$$

$$M_o = \frac{(0.145 \text{ kipft}) + ((-0.093 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.048333 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(0.048333 \text{ kipft/ft})}{(-0.031 \text{ kip/ft})}$$

$$E = 1.5591 \text{ ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (0.048333 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (-0.031 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (0.048333 \text{ kipft/ft})) + (4 \times (-0.031 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.8492 \text{ ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\, b) \left[1 - \left[3 \left(\frac{4\, E}{L_e} + 3\right) \left(\frac{a}{L_e}\right)^2\right] + \left[4 \left(\frac{3\, E}{L_e} + 2\right) \left(\frac{a}{L_e}\right)^3\right]\right]$$

$$V_{max} = ((-0.031 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.5591 \text{ ft})}{(8 \text{ ft})} + 3\right) \times \left(\frac{(5.8492 \text{ ft})}{(8 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.5591 \text{ ft})}{(8 \text{ ft})} + 2\right) \times \left(\frac{(5.8492 \text{ ft})}{(8 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.094905 \text{ kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\, b\, L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2\, L_e}\right) - \left[\left(\frac{4\, E}{L_e} + 3\right) \left(\frac{a}{2\, L_e}\right)^3\right] + \left[\left(\frac{3\, E}{L_e} + 2\right) \left(\frac{a}{2\, L_e}\right)^4\right]\right]$$

$$M_{max} = ((-0.031 \text{ kip/ft}) \times (36 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(1.5591 \text{ ft})}{(8 \text{ ft})} + \frac{(5.8492 \text{ ft})}{2 \times (8 \text{ ft})}\right) - \left[\left(\frac{4 \times (1.5591 \text{ ft})}{(8 \text{ ft})} + 3\right) \times \left(\frac{(5.8492 \text{ ft})}{2 \times (8 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.5591 \text{ ft})}{(8 \text{ ft})} + 2\right) \times \left(\frac{(5.8492 \text{ ft})}{2 \times (8 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.31395 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

Required reinforcement due to axial load, $A_{st,required}$
22.4.2.2, 10.6.1.1 $A_{st,required}$

$$A_{st,required} = Min\left[\frac{\frac{P}{\phi\,\alpha} - \left(0.85\, f'_{ck}\, A_g\right)}{f_{yk} - \left(0.85\, f'_{ck}\right)}, \left(0.08\, A_g\right)\right]$$

$$A_{st,required} = Min\left[\frac{\frac{(14.569 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -36.918 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

$$A_{min} = Max\left[A_{st,required}, \left(0.0018\, A_g\right)\right]$$

$$A_{min} = Max\left[\left(-36.918 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

$$n_{rebar} = \frac{A_{min}}{A_{rebar}}$$

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

$$A_{st} = n_{rebar}\,\frac{\pi\, d_{bar}^2}{4}$$

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

$$Ratio = \frac{A_{min}}{A_{st}}$$

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

$$s_{rebar} = Max\left[1.5, \left(1.5\, d_{bar}\right)\right]$$

$$s_{rebar} = Max\left[1.5, (1.5 \times (0.625 \text{ in}))\right]$$

$$s_{rebar} = 1.5 \text{ in}$$

Ties:

25.7.2.2 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)
25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

$$s_{ties} = Min\left[\left(16\, d_{bar}\right), \left(48\, d_{ties}\right), D\right]$$

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

$$s_{ties} = 10 \text{ in}$$

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

	Axial Compression Strength (ACI 318-19, LRFD)	

22.4.2.2 ϕP_N - Allowable axial compressive strength

$$\phi P_N = \phi\, 0.85\ \left[\left(0.85\, f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\, A_{st})\right]$$

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(1017.9\text{ in}^2\right) - \left(1.8408\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(1.8408\text{ in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\text{ kip}$$

$Ratio$ - Capacity

$$Ratio = \frac{P}{\phi P_N}$$

$$Ratio = \frac{(14.569\text{ kip})}{(1253.9\text{ kip})}$$

$$Ratio = 0.011619$$

Status: **PASS**
Ratio: **0.010**

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\text{ in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\text{ in})$$

$$d = 28.8\text{ in}$$

22.5.5.1.3 λ_s - size effect modification factor

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\text{ in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$,

22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

$$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\text{ psi})} \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,max} = 186.09\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 14.569\text{ kip} \rightarrow 14569\text{ lbf}$,

22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

$$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + \frac{(14569\text{ lbf})}{6 \times (1017.9\text{ in}^2)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,a} = 76.911\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$,

22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

$$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + (0.05 \times (2500\text{ psi}))\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,b} = 204.04\text{ kip}$$

V_c - Governing shear strength of concrete

$$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$

$$V_c = Min\left[(186.09\text{ kip}), (76.911\text{ kip}), (204.04\text{ kip})\right]$$

$$V_c = 76.911 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

$$V_{s,a} = 8 \sqrt{f'_{ck}}\, b_w\, d$$

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi\, d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$

$$A_v = 0.11045 \text{ in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

V_s - Governing shear strength of steel

$$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$

$$V_s = MIN\left[(414.72 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\ (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((76.911 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.803 \text{ kip}$$

Considering x-direction:

$V_{max} = 10.806 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(10.806 \text{ kip})}{(74.803 \text{ kip})}$$

$$Ratio = 0.14446$$

Status: **PASS**
Ratio: **0.140**

Considering z-direction:

$V_{max} = 0.094905 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(0.094905 \text{ kip})}{(74.803 \text{ kip})}$$

$$Ratio = 0.0012687$$

Status: **PASS**
Ratio: **0.000**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

	$$S_m = 4580.4 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$ $$\phi M_{n,2} = 527.23 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$ $$\phi M_n = 62.027 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 40.083 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(40.083 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.64623$$	Status: **PASS** Ratio: **0.650**
	Considering z-direction: $M_{max} = 0.31395 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.31395 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.0050615$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

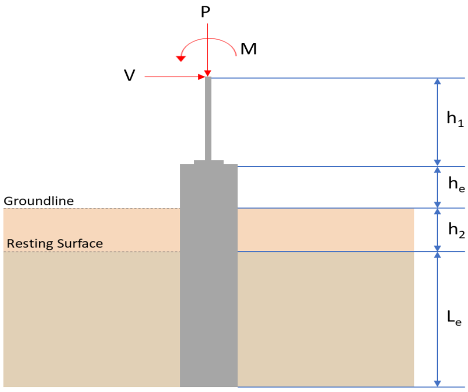
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	9.624	14.569
V_x (kip)	-2.598	-4.357
V_z (kip)	0.059	0.093
M_x (kipft)	0.093	0.145
M_z (kipft)	21.375	35.848

Material Properties

$f'_{ck} = 2.5\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0\ \mathrm{ft}) + (0\ \mathrm{ft}) + (0\ \mathrm{ft})$$

$$H = 0\ \mathrm{ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{D}$$

$$H_o = \frac{(-2.598\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.866\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\ H)}{D}$$

$$M_o = \frac{(21.375\ \text{kipft}) + ((-2.598\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 7.125\ \text{kipft/ft}$$

Required depth of embedment in earth:

$$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,x} = 6.9159\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.059\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.019667\ \text{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{D}$$

$$M_o = \frac{(0.093\ \text{kipft}) + ((0.059\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.031\ \text{kipft/ft}$$

Required depth of embedment in earth:

$$L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,z} = 1.96\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

$L_{e,req}$ - Depth of pile required,

$$L_{e,req} = MAX[L_{e,x}, L_{e,z}]$$

$$L_{e,req} = MAX[(6.9159\ \text{ft}), (1.96\ \text{ft})]$$

$$L_{e,req} = 6.916\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8\ \text{ft}$$

$Ratio$ - Embedded depth

$$Ratio = \frac{L_{e,req}}{L_e}$$

$$Ratio = \frac{(6.916\ \text{ft})}{(8\ \text{ft})}$$

$$Ratio = 0.8645$$

Status: **PASS**
Ratio: **0.860**

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

$$q = \frac{P_v}{A}$$

$$q = \frac{(9.624\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.3615\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

$$Ratio = \frac{q}{q_a}$$

$$Ratio = \frac{\left(1.3615\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.68076$$

Status: **PASS**
Ratio: **0.680**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

$$L/D = \frac{L}{D}$$

$$L/D = \frac{(8\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.6667$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.866\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.125\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (7.125\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.866\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (7.125\ \mathrm{kipft/ft})) + (4 \times (-0.866\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5955\ \mathrm{ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{1.178\ [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\ [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (7.125\ \mathrm{kipft/ft})) + (3 \times (-0.866\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\ 2}}{(8\ \mathrm{ft})^2 \times [(3 \times (7.125\ \mathrm{kipft/ft})) + (2 \times (-0.866\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = 0.14574\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (7.125\ \mathrm{kipft/ft})) + ((-0.866\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = 1.0783\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\,\frac{a}{2}$$

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5955\ \mathrm{ft})}{2}$$

$$p_a = 0.41966\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{\left(0.14574\ \mathrm{kip/ft^2}\right)}{\left(0.41966\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.34729$$

Status: **PASS**
Ratio: **0.350**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.0783\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.89857$$

Status: **PASS**
Ratio: **0.900**

Considering z-direction:

$H_o = 0.019667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.031\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (0.031\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (0.019667\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.031\ \mathrm{kipft/ft})) + (4 \times (0.019667\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.8479\ \mathrm{ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{1.178\ [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\ [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.031\ \mathrm{kipft/ft})) + (3 \times (0.019667\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\,2}}{(8\ \mathrm{ft})^2 \times [(3 \times (0.031\ \mathrm{kipft/ft})) + (2 \times (0.019667\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = 0.016038\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.031\ \mathrm{kipft/ft})) + ((0.019667\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = 0.0323\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\, \frac{a}{2}$$

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8479\ \mathrm{ft})}{2}$$

$$p_a = 0.43859\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{\left(0.016038\ \mathrm{kip/ft^2}\right)}{\left(0.43859\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.036567$$

Status: **PASS**
Ratio: **0.040**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

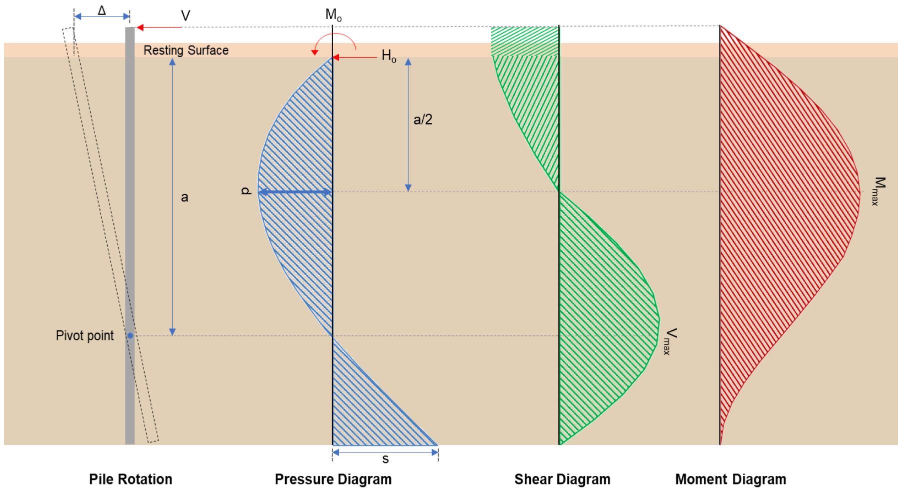
$Ratio$ - Lateral soil capacity

$$Ratio = \frac{}{p_s}$$

$$Ratio = \frac{\left(0.0323\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.026917$$

Status: **PASS**
Ratio: **0.030**



Shear force and Bending moment (x-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{D}$$

$$H_o = \frac{(-4.357\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.4523\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\ H)}{D}$$

$$M_o = \frac{(35.848\ \mathrm{kipft}) + ((-4.357\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 11.949\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(11.949\ \mathrm{kipft/ft})}{(-1.4523\ \mathrm{kip/ft})}$$

$$E = 8.2277\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\ M_o\ L_e) + \left(3\ H_o\ L_e^2\right)}{(6\ M_o) + (4\ H_o\ L_e)}$$

$$a = \frac{(4 \times (11.949\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-1.4523\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (11.949\ \mathrm{kipft/ft})) + (4 \times (-1.4523\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5955\ \mathrm{ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\ D)\left[1 - \left[3\left(\frac{4\ E}{L_e} + 3\right)\left(\frac{a}{L_e}\right)^2\right] + \left[4\left(\frac{3\ E}{L_e} + 2\right)\left(\frac{a}{L_e}\right)^3\right]\right]$$

$$V_{max} = ((-1.4523\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.2277\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5955\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.2277\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5955\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.806 \text{ kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\, D\, L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2\, L_e} \right) - \left[\left(\frac{4\, E}{L_e} + 3 \right) \left(\frac{a}{2\, L_e} \right)^3 \right] + \left[\left(\frac{3\, E}{L_e} + 2 \right) \left(\frac{a}{2\, L_e} \right)^4 \right] \right]$$

$$M_{max} = ((-1.4523 \text{ kip/ft}) \times (36 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(8.2277 \text{ ft})}{(8 \text{ ft})} + \frac{(5.5955 \text{ ft})}{2 \times (8 \text{ ft})} \right) - \left[\left(\frac{4 \times (8.2277 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.5955 \text{ ft})}{2 \times (8 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (8.2277 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.5955 \text{ ft})}{2 \times (8 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 40.083 \text{ kipft}$$

Shear force and Bending moment (z-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.093 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.031 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{D}$$

$$M_o = \frac{(0.145 \text{ kipft}) + ((0.093 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.048333 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(0.048333 \text{ kipft/ft})}{(0.031 \text{ kip/ft})}$$

$$E = 1.5591 \text{ ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (0.048333 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (0.031 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (0.048333 \text{ kipft/ft})) + (4 \times (0.031 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.8492 \text{ ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\, b) \left[1 - \left[3 \left(\frac{4\, E}{L_e} + 3 \right) \left(\frac{a}{L_e} \right)^2 \right] + \left[4 \left(\frac{3\, E}{L_e} + 2 \right) \left(\frac{a}{L_e} \right)^3 \right] \right]$$

$$V_{max} = ((0.031 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.5591 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.8492 \text{ ft})}{(8 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (1.5591 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.8492 \text{ ft})}{(8 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.094905 \text{ kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\, b\, L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2\, L_e} \right) - \left[\left(\frac{4\, E}{L_e} + 3 \right) \left(\frac{a}{2\, L_e} \right)^3 \right] + \left[\left(\frac{3\, E}{L_e} + 2 \right) \left(\frac{a}{2\, L_e} \right)^4 \right] \right]$$

$$M_{max} = ((0.031 \text{ kip/ft}) \times (36 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(1.5591 \text{ ft})}{(8 \text{ ft})} + \frac{(5.8492 \text{ ft})}{2 \times (8 \text{ ft})} \right) - \left[\left(\frac{4 \times (1.5591 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.8492 \text{ ft})}{2 \times (8 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (1.5591 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.8492 \text{ ft})}{2 \times (8 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.31395 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

Required reinforcement due to axial load, $A_{st,required}$
22.4.2.2, 10.6.1.1 $A_{st,required}$

$$A_{st,required} = Min\left[\frac{\frac{P}{\phi\ \alpha} - \left(0.85\ f'_{ck}\ A_g\right)}{f_{yk} - \left(0.85\ f'_{ck}\right)}, \left(0.08\ A_g\right)\right]$$

$$A_{st,required} = Min\left[\frac{\frac{(14.569 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -36.918 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

$$A_{min} = Max\left[A_{st,required}, \left(0.0018\ A_g\right)\right]$$

$$A_{min} = Max\left[\left(-36.918 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

$$n_{rebar} = \frac{A_{min}}{A_{rebar}}$$

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

$$A_{st} = n_{rebar}\ \frac{\pi\ d_{bar}^2}{4}$$

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

$$Ratio = \frac{A_{min}}{A_{st}}$$

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

$$s_{rebar} = Max\left[1.5, \left(1.5\ d_{bar}\right)\right]$$

$$s_{rebar} = Max\left[1.5, (1.5 \times (0.625 \text{ in}))\right]$$

$$s_{rebar} = 1.5 \text{ in}$$

Ties:

25.7.2.2 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)
25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

$$s_{ties} = Min\left[\left(16\ d_{bar}\right), \left(48\ d_{ties}\right), D\right]$$

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

$$s_{ties} = 10 \text{ in}$$

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

$$\phi P_N = \phi\, 0.85\, \left[\left(0.85\, f'_{ck}\, [A_g - A_{st}]\right) + (f_{yk}\, A_{st})\right]$$

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

$$Ratio = \frac{P}{\phi P_N}$$

$$Ratio = \frac{(14.569\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.011619$$

Status: **PASS**
Ratio: **0.010**

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

$$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}, P = 14.569\ \text{kip} \rightarrow 14569\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

$$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(14569\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.911\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,
22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

$$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

$$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$

$$V_c = Min\left[(186.09\ \text{kip}), (76.911\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.911\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

$$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi\, d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$

$$A_v = 0.11045\ \text{in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

$$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\ (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((76.911\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.803\ \text{kip}$$

Considering x-direction:

$V_{max} = 10.806\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(10.806\ \text{kip})}{(74.803\ \text{kip})}$$

$$Ratio = 0.14446$$

Status: **PASS**
Ratio: **0.140**

Considering z-direction:

$V_{max} = 0.094905\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(0.094905\ \text{kip})}{(74.803\ \text{kip})}$$

$$Ratio = 0.0012687$$

Status: **PASS**
Ratio: **0.000**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

$$S_m = 4580.4\ \text{in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),
Allowable flexural strength:
M_n shall be the lesser of:
$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$

$$\phi M_{n,1} = 62.027kipft$$

14.5.2.1b $\phi M_{n,2}$

$$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$

$$\phi M_{n,2} = 527.23\ \text{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

$$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$

$$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$

$$\phi M_n = 62.027\ \text{kipft}$$

Considering x-direction:

$M_{max} = 40.083\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

$$Ratio = \frac{M_{max}}{\phi M_n}$$

$$Ratio = \frac{(40.083\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.64623$$

Status: **PASS**
Ratio: **0.650**

Considering z-direction:

$M_{max} = 0.31395\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

$$Ratio = \frac{M_{max}}{\phi M_n}$$

$$Ratio = \frac{(0.31395\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.0050615$$

Status: **PASS**
Ratio: **0.010**